
I. *Experiments upon Metals, made with the Burning-Glaſs of the Duke of* Orleans. *By Monſieur* Geoffroy, *F. R. S.*

THE Duke of *Orleans*, out of the deſire he has to promote uſeful Arts and Sciences, having permitted ſuch of the Royal Academy of Sciences as have had moſt Experience in ſubjects of this Nature, to make uſe of his Burning-glaſs; I took this Opportunity to examine the different Changes that Metals ſuffer when placed in the Focus of this Glaſs, whoſe Heat and Efficacy far ſurpaſſes the force of our common Fires.

The Burning glaſs is three Foot in Diameter; it collects the Rays of the Sun at ten Foot diſtance, where it forms a Focus of about three Inches over, which is again contracted by means of an other Glaſs-Lens to an Inch Diameter, and conſequently is render'd three times as ſtrong.

I ſhall only relate here what I have obſerv'd upon the four Imperfect Metals, *viz.* Iron, Copper, Tin, and Lead: And ſhall ſay nothing at preſent of Gold or Silver; becauſe as their Analyſis ſeems to me much more difficult than that of the other Metals; I ſhall forbear Inquiries upon them, 'till I have examined as far as poſſible into the Nature and Compoſition of the former.

What was a great hindrance to me in making theſe Experiments in the Focus of the Glaſs, was the difficulty I had to find any Matter capable of holding the Metals in fuſion.

Charcoal, which is commonly made uſe of, is indeed a very proper ſubſtance; but it is impoſſible with it to vitrify any one of the Metals: The Particles of the Metal, when held any long time in fuſion in the Focus of the Glaſs, diſſipate and fly away in Fume or ſmall Particles; and as long as any part remains, that little that does remain, is always Metallick, until the whole be quite evaporated.

The reaſon of which I take to be this. Charcoal is a ſubſtance deeply impregnated with Oily or Sulphurous Parts (if I may ſo call them.) The firſt Effect that Fire has upon Metals is to ſeparate the ſulphurous Parts: now, if in proportion as the Sulphur is ſeparated from the Metal, the Body that ſupports the Metal furniſhes it anew with other ſulphurous Parts, the other Principles will never ſeparate, and the Metal will always remain Metal. And nothing but the greateſt degree of Fire is able to raiſe and ſeparate the Sulphur, and that but by little and little, and in very ſmall Particles.

I had then recourſe to an other Matter, that could not any ways be ſuſpected of containing any Oily Parts. Mr. *Tſchirnhaus*, to whom we are obliged for Making of theſe large Glaſſes, and the firſt Experiments that have been made with them, ſays, he has vitrified Metals by holding them in *China* ware. It is true, this ſucceeds pretty well, provided the Pieces be very thick, and the Glazing taken off: But the difficulty I had to find a ſufficient quantity of thick and proper *China* ware to make all theſe Experiments, forced me to have recourſe to more common ſubjects, as well as ſuch, if poſſible, as were leſs capable of melting.

Of all the different ſorts of Matter that I made Tryal of, what ſeem beſt were the Common Coppels and Plates of gray Fire-ſtone. The Coppels hold the Metal a long time in fuſion in the Focus of the Glaſs without melting; excepting Lead, which eaſily runs thro' them as ſoon as it vitrifies, and helps to diſſolve them. The Plates of Fire-ſtone bear the Heat of the Focus much longer than any other Matter; but great care is to be taken in heating them without breaking, 'till they become red-hot, and when they are hot the leaſt cold Air makes them melt. Nevertheleſs this is the only ſubſtance that I have uſed with moſt ſucceſs, to hold Metals a long time in fuſion, tho' with the greateſt caution that was poſſible, to avoid the Inconveniences aforemention'd.

An other thing that has hinder'd me from carrying on theſe Inquiries upon Metals ſo far as I could have wiſhed, has been the few clear Days we have had for theſe two Years paſt; for the greateſt part of theſe Experiments require a bright, ſtrong, and conſtant Sun to keep the Matter a long time in perfect fuſion: And I have ſcarce had, for this laſt Year, above three or four ſuch days as I could wiſh for; the Sky having been almoſt every day cover'd with Clouds about Noon, which is the only time of the day fit for theſe Experiments.

I come now to the Particulars of what Experiments I have made; and ſhall begin with thoſe on Iron.

Of Iron.

I placed in the Focus of the Burning-glaſs a piece of forged Iron of about a Drahm weight: It turn'd red-hot, and its ſurface was cover'd with a black Matter like Pitch or Tar. If one withdraws the Iron out of the Focus in this ſtate, this Matter fixes itſelf on the ſurface of the Metal, and there forms a ſmall Skin or very fine blackiſh Scale, which is commonly very eaſily ſeparated by ſtriking upon it; and that part of the Iron that was cover'd with this Scale appears blacker than ordinary. This Scale is ſome of the ſulphurons part of the Iron that riſes to and Surface of the Metal when it is ready to melt, the there remains for ſome time before it exhales. It

It is plainly this ſulphurous part that riſes upon Iron and poliſh'd Steel when heated, and gives them all thoſe different Colours, from a Yellow, to a Violet, Water-Colour, or Black.

If one continues to hold this Piece of Iron on the Charcoal, it intirely melts; and at the ſame time caſts forth very bright Sparkes in a great quantity, ſometimes to above a foot diſtance from the Coal.

If one ſaves what flies off during this ſparkling, by holding a Sheet of Paper under the Coal; we find that they are ſo many very ſmall Globules of Iron, and the greateſt part of them hollow.

All the Iron that is held in fuſion upon the Coal, flies away in ſparkles after this manner, 'till none remains. Sometimes the Metal leaves off ſparkling, when the Coal is in part conſumed, and cover'd with a Bed of Cinders, upon which lies the melted Iron. For as the ſparkling of the Iron ſeems to me to proceed from nothing but the oily parts of the Coal acting upon thoſe of the Metal, the Cinders hinder this Oil from paſſing from the Coal to the Iron, ſo that it remains quietly in fuſion. But if thro' any ſhake, or the like accident, the Cinders are ſo removed that the Iron comes to touch immediately the Coal, it will begin to ſparkle afreſh. Sometimes the Heat that keeps in fuſion the Metal, vitrifies alſo the Cinders; and this vitrified Matter mixing with the Metal makes a conſiderable Ebullition. If one at this inſtant withdraws the Metal out of the Focus, it appears half vitrified, or reduced to a blackiſh friable Maſs. Othertimes this vitrified Matter ſwims on the ſurface of the Metal, and there forms it ſelf into Drops, that are ſometimes clear and tranſparent, and other times opake, according as it is more or leſs mixed with the Metal.

Furthermore, if after having let the melted Iron cool upon the Coal, one expoſes it again to the *Focus* of the Glaſs upon the Stone, it ſparkles afreſh till it is all conſumed; which common Iron will not do, that has not been expoſed to the heat of the *Focus* upon Charcoal. This Sparkling probably proceeds from the ſudden Rarifaction of the Oily parts of the Coal, with which the Pores of the Iron are ſo plentifully ſaturated; or perhaps it may be cauſed by the Salts of the Iron acting on the Oil of the Coal.

I expoſed to the *Focus*, upon a Stone-ſlate, Iron and Steel: they grew red hot, and melted without crackling or caſting off any Sparkes: they ſmoak'd very conſiderably, and the melted Metal turn'd by little and little like an Oil. After having withdrawn this melted Matter out of the Focus, it fix'd in a Regulus-like, friable Maſs, and appear'd ſometimes lightly ſtriated, or ſhot into ſharp Points like Needles. Tho' this matter does not appear at all tranſparent, yet we may look on it as the beginning of Vitrification, or a middle ſtate between Metal and Glaſs; for it would vitrify in the end like other Metals, if one could hold it a ſufficient time in the Focus without melting or mixing with what ſuſtains it: But continuing it long in the Focus, the extream Heat of the Sun, that is neceſſary to keep it in perfect fuſion, melts likewiſe the Stone or Coppel that contains it, the reſult of which mixture is a brown or greyiſh ſort of Enamel.

We may then take this Regulus Maſs to be a half vitrified Iron, by reaſon it is deprived of great part of its Sulphur. If one adds to this Maſs a Sulphur like that which was taken from it, from being friable it turns very hard and malleable; and the dulneſs it had before, changes to the brightneſs of a Metal. This is what I have experienc'd in expoſing again this Matter to the Focus upon Charcoal: it melts, and ſo continues a conſiderable time

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in fuſion without ſparkling, but at laſt it ſparkles with the ſame briskneſs as Iron itſelf; and when withdrawn from the Focus, appears nothing different from melted Iron.

It appears from theſe Experiments, that Iron contains a ſulphur or oily Subſtance, that renders it bright, malleable, and eaſy to melt.

That this Sulphur is raiſed by the Fire of the Sun, when the Metal is for ſome time held in fuſion in the Focus of the Glaſs.

That this ſame Sulphur may be raiſed by the Flame of common Fire, which tho' not ſtrong enough to melt the Iron, yet is able to reduce it to an Eſchar or ſort of Ruſt.

That Iron deprived of this ſulphurous part, melts into a Regulus, or brittle and friable Maſs, in colour much like Antimony.

That if one can hold a ſufficient quantity of this Matter long enough in the Focus by itſelf, without melting or mixing with the Body that contains it, it perfectly vitrifies.

That this Glaſs or metallick Regulus, with the help of a little Oil, returns to its former ſtate of a Metal.

That it reaſſumes this metallick Form upon Charcoal, by drawing thence this oily Subſtance.

That, in ſhort, this oily part contain'd in the Coal, is little different from the Sulphur of Iron. Nevertheleſs we muſt imagine it to differ in ſome particulars, in that melted Iron that has been ſaturated with it, crackles and ſparkles very much when melted again upon the Stone or Coppel.

Iron being the only Metal in which I have obſerved this ſparkling, I take it to be a Property peculiar only to Iron and not to any other Metal. Perhaps we may attribute it to the vitriolick Salt that this Metal ſo plentifully abounds with, which is very greedy of Sulphurs.

To this ſame greedineſs alſo, with which the vitriolick Salt of Iron abſorbs the oily part of the Coal, we may attribute the eaſineſs with which Iron conſumes the Coal; for there is no other Metal that ſo ſoon waſts the Coal in the Focus of the Glaſs, as Iron does.

An other Obſervation upon Iron is, that it is the only one of the four imperfect Metals, on which vitrified Drops ariſe while it is in fuſion upon the Coal: The reaſon of which I have not yet been able to diſcover.

Of Copper.

Copper expoſed to the Focus of the Burning-glaſs, at firſt turns white on its ſurface, and afterwards grows black, and is covered with a kind of Skin, or black, furrow'd, and uneven Scales, till at laſt it quite melts.

I have withdrawn this Metal out of the Focus as ſoon as this white colour has appear'd, and after it has been cold, found nothing extraordinary on its ſurface, which has again by little and little recover'd very near the ſame Colour as it had before.

I have not been able to diſcover from whence this white Colour proceeds; unleſs we may attribute it to ſome Volatile Arſenical Salt contain'd in the Copper, and driven by extreamity of Heat to the ſurface of the Metal; or whether it purely proceeds from the alteration that is made in the groſſer parts of the ſurface of the Metal when it begins to melt. The black colour that Copper afterwards takes, ſeems to be cauſed by the ſulphurous Matter that melts firſt in this Metal as well as Iron, and is raiſed to its ſurface by the extream Heat.

I placed a piece of Copper in the Focus upon Charcoal: It melted, and emitted a very thin Fume, and by little and little diminiſhed till it was all evaporated.

I put a piece of red Copper on a Coppel into the Focus of the Glaſs: it melted, and ſent forth ſome thin Fumes; and after it had been ſome time in fuſion, it turn'd liquid like an Oil. I withdrew this melted matter, and as it grew cold, it fix'd into a Regulus of a reddiſh brown colour, which was hard, brittle, and not ductile under the Hammer. If one breaks it, it turns into a red Powder like Cinabar of Antimony; and when view'd with a Microſcope, appears ſo many little, red, tranſparent Grains like ſmall Rubies; in ſo much that one would readily take this Regulus to be a deep colour'd red Glaſs.

I endeavoured to make this vitrified Copper ſpread abroad in melting, by mixing it with common white Glaſs; for which end I powder'd ſome of this vitrified Copper and common Glaſs, and mixing them melted them together; but the Mixture when in fuſion took at firſt a beautiful green Colour, and continuing it longer in the Focus, it turn'd blewiſh. I believe we may attribute this change of Colour to the Alcali Salts of the Glaſs acting on the Particles of Copper; for thoſe Salts uſually draw a green or blewiſh Tincture from this Metal.

To preſerve therefore this red Colour of the vitrified Copper, when mix'd with common Glaſs, I made uſe of this Expedient. I melted in the Focus upon a Coppel a piece of Copper, and as ſoon as it began to vitrify I caſt upon it ſome common Glaſs; as ſoon as the Glaſs was melted I took them together out of the Focus without confuſing them; and as ſoon as they were cold, ſeparated the Regulus from the Glaſs as well as poſſible; and pick'd out of it ſome pieces of the Glaſs, loaded with ſome very ſmall red tranſparent Particles of the Regulus.

This vitrified Copper is then nothing but Copper deprived, by means of heat, of the ſulphurous part, that gave it the form of a Metal. A proof that this metallick form proceeds from nothing elſe but this Sulphur, is, that if one expoſes this vitrified Copper to the Focus upon Charcoal, it reaſſumes in a little time the Colour and Conſiſtence of melted Copper; and as it grows cold, fixes into a good red malleable Copper, as fine and hard as it was before it was vitrified.

It follows from theſe Experiments, that the Baſis of Copper is a red Earth ſuſceptible of Vitrification.

That this Earth receives its metallick Form from a ſulphurous ſubſtance, in appearance no ways different from the Oil of Vegetables or Animals.

That one may deprive Copper of this Oil, by holding it long enough in the Focus, or by calcining it in the Flame of common Fire.

That Charcoal reſtores again this oily Part to Copper, and at the ſame time its metallick Form.

It appears further, that the Oil of the Coal has not ſo conſiderable an effect upon Copper, as it has upon Iron.

Copper expoſed a long time to the Focus upon a Stone or Coppel, fumes very much, and diminiſhes in weight very conſiderably. I don't think that this fume is only the ſulphurous part of the Metal, the Evaporation of which muſt be inſenſible; but I believe that with this Oil there is mixed a great deal of the earthy, vitrifiable part of the Metal, which the heat of the Sun ſublimes and raiſes in Flowers.

Of Tin.

Tin expoſed upon Coal to the Focus of the Burning-glaſs, melts, and emits a groſs, white, thick Fume, until it is all conſumed in Vapours.

If one melts Tin upon a Coppel in the Focus of the Glaſs, it fumes very much, and its ſurface is cover'd with a white rarified Calx; on which by little and little ariſes a tuft, or heap of ſharp, needle-like, tranſparent, criſtalline Particles, conſiſting of an infinite number of ſmall Points.

If one continues to hold this Maſs in the Focus upon the Stone, theſe Criſtals at lenghth leave off fuming, and remain fixt, while the Stone melts and vitrifies.

I took Calx of Tin, which is Tin reduced to a grey Powder by means of Fire, that has taken away by Calcination great part of its oily Subſtance, and expoſed it on a Coppel to the Focus, where it fumed again very much, and was reduced into ſharp chriſtalline Particles conſiſting of other ſmall Points.

In re-expoſing theſe chryſtalline Particles to the Focus upon Charcoal, they melted very eaſily, and took again the Form of Tin; the Coal having furniſhed them with the ſulphurous part that the Fire had before taken away. Every body knows, that if one adds any Fat, or the like inflammable Matter, to the Calx of Tin when red-hot in the Crucible, it reaſſumes immediately the form of Tin.

Theſe Experiments ſhow, that Tin contains a Sulphur that is very eaſily ſeparated, ſince common Fire can do it ſo readily; and that this Metal calcined, or deprived of its Sulphur, is eaſily ſaturated again with it from the oily part of any inflammable Matter whatſoever.

It proves alſo, that the metallick Earth which is the Baſis of Tin, is a Criſtalline Earth, very difficult to be melted; ſince common Fire cannot vitrify this Metal by it ſelf, and that the heat of the Sun, in the Focus of this large Burning-Glaſs of the Palace-Royal, cannot perfectly melt the Calx into which this Metal is reduced. We may preſume that the Criſtalliſation, or reducing of this Metal into ſharp-pointed Particles, proceeds from the force the Sun's breaking and melting together into a Sodder (if I may ſo ſpeak) ſome of theſe ſmall Criſtals, by degrees as the ſulphurous part leaves them; it not being ſtrong enough to melt them all down together in one intire Maſs.

Of Lead.

I took Lead, and held it in fuſion upon Charcoal in the Focus of the Glaſs: it all waſted away in abundance of Fumes.

I expoſed the like quantity of Lead upon a Stone to the Focus, where it caſt forth great quantities of fumes, and by little and little changed into a fluid Liquor like Oil or melted Roſin. This Liquor, as it grew cold, fix'd into Glaſs; which has this peculiar to it ſelf, that it is diſpoſed into Plates like *Venetian* Talk, and that it is flabby, ſoft to the touch, tranſparent, and in ſome parts of a greeniſh or reddiſh Yellow.

In continuing this matter in the Focus, it ſpread upon the Stone like Varniſh; and at laſt penetrating it, help'd to melt it.

I placed this talky Earth in the Focus upon Charcoal: It melted, and in a little time after reaſſumed the form of melted Lead. I withdrew it from the Focus, and having let it cool, found it nothing different from Lead.

Theſe Experiments ſhow, that there is in Lead, as well as the other imperfect Metals, a ſulphurous part, that is eaſily ſeparated by common Fire or the heat of the Sun; and that this Metal has for its Baſis a foliated or talky Earth

Of Quickſilver.

I ſhall add here ſome Experiments that I have made upon Quickſilver; tho' I can't yet draw any poſitive Concluſions from them, not having proſecuted them ſo far as is neceſſary for that purpoſe.

I placed Quickſilver in the Focus of the Burning-glaſs upon Charcoal, upon the Coppel, and upon the Stone: It all immediately diſperſed, and exhaled in a very thick Fume.

I expoſed upon the Stone to the Focus ſome *Mercury precipitate per ſe*, in a degree of heat equal to that of digeſtion: It ſeem'd to melt, but preſently diſperſed in Vapours: only there remained a ſmall quantity of a very rarified Duſt, like a Froath or Scum; but continuing it in the Focus, it melted, and gathered into a yellowiſh Glaſs, in which one might diſtinguiſh ſome Particles of Metal like Silver.

I expoſed ſome Mercury *Precipitate per ſe* upon Charcoal: It fumed very much; and as it melted one might ſee little Globules of Mercury unite and form themſelves together upon the Coal, but they diſperſed again preſently in Vapours.

Theſe Experiments ſeem to prove, that there is in Quickſilver a Sulphur that may be ſeperated by a very gentle heat, ſuch as that of Digeſtion.

That as ſoon as this Sulphur is taken away, it loſes its Fluidity and Brightneſs.

That the Baſis of Mercury is a Calx, or red Earth.

That this Calx does not melt into Glaſs as the Calx of other Metals, becauſe it is too Volatile, and as ſoon as it melts is evaporated by the heat.

That if one reſtores to this Calx a Sulphur, by expoſing it again to the Focus upon Charcoal, it reaſſumes immediately its metallick Brightneſs and Fluidity, and becomes Quickſilver.

I cannot tell whether this light Earth, that remains upon the Stone after the evaporation of the Calx of the Mercury, be a part of the Earth of the Mercury more exactly deprived of its Oil, and conſequently more fixt and proper for Vitrification; or whether it may not be ſome Matter foreign to the Mercury, that fixes it ſelf, and remains behind at its Evaporation. But this I ſhall examine more particularly hereafter.

The Reſult of all theſe Experiments is, that theſe four Metals which we call imperfect, *viz.* Iron, Copper, Tin, and Lead, are compoſed of a ſulphur or oily Subſtance, and of a metallick Earth capable of Vitrificacation.

That from this Sulphur proceeds the Opacity, Brightneſs, and Malleability of a Metal.

That this metallick Sulphur does not appear at all different from the Oil of Vegetables or Animals.

That it is the ſame in Mercury as in the four imperfect Metals.

That theſe four Metals have for their Baſis an Earth ſuſceptible of Vitrification.

That this Earth is different in every one of theſe four Metals; in that it vitrifies differently in each of them.

And that on this difference in Vitrifying depends the difference of Metals.

It remains that I ſhould examine more particularly the Nature of theſe Earths or metallick Vitrifications; to know if any other Principles or Subſtances may be ſeperated from them: But this I ſhall endeavour to do hereafter, in proſecuting the Analyſis of theſe Metals as far as poſſible.